(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 223 576 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
17.07.2002 Bulletin 2002/29

(51) Int Cl.7: G11B 7/135

(21) Application number: 01306958.8

(22) Date of filing: 16.08.2001

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 28.12.2000 KR 2000084211

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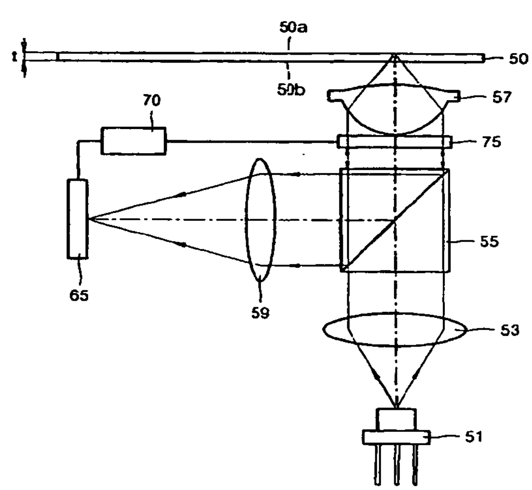
(54) Optical pickup capable of detecting thickness variation of recording medium, and/or capable of compensating for spherical aberration caused by thickness variation of recording medium

(57) An optical pickup is provided,, in which a light beam division and detection unit (65) is used to determine variation in thickness of a recording medium (50). The light beam division and detection unit (65) is arranged for dividing a light beam passed back through an objective lens (57) and an optical path changer (55) after having been reflected from a recording medium (50). The unit (65) is constructed as a single photodetector having a divided configuration, or a light beam divider (160) and a plurality of photodetectors (165a,b), which can detect divided light beam portions, taking into account variation in the intensity distribution of light caused by thickness variation of the recording medium. The optical pickup allows detection of variation of thickness of the recording medium without a need to install an astigmatism lens at the light receiving side of the optical pickup. Spherical aberration caused by thickness variation of the recording medium can be corrected by driving a spherical aberration compensation element (75) or a collimating lens (53) along the optical axis according to the detected thickness variation signal using an actuator.

FIG. 5



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Description

[0001] The present invention relates to an optical pickup, and more particularly, to an optical pickup capable of detecting thickness variation of a recording medium, and/or capable of compensating for spherical aberration caused by the thickness variation of a recording medium.

[0002] In general, information recording/reproduction density increases as the size of a spot focused on a recording medium by an optical pickup apparatus becomes smaller. The shorter the wavelength (λ) of light used and the larger the numerical aperture (NA) of an objective lens, the smaller the size of light spot, which is expressed by equation (1):

$$\textit{Size of light spot} \propto \lambda/NA \quad \ldots(1) \qquad (1)$$

[0003] To reduce the size of light spot focused on the recording medium for a higher recording density, there is a need to construct an optical pickup with a short wavelength light source, such as a blue semiconductor laser, and an objective lens having a larger NA. Currently of interest in this technical field is a format for increasing recording capacity up to 22.5 GB with a 0.85-NA objective lens, and for reducing the thickness of a recording medium to 0.1 mm so as to prevent degradation of performance caused by tilting of the recording medium. Here, the thickness of recording medium means the distance from a light incident surface of the recording medium to an information recording surface.

[0004] As shown in equation (2) below, spherical aberration W_{40d} is proportional to the fourth power of the NA of the objective lens and to the deviation of the thickness of recording medium. For this reason, if an objective lens with a high NA of about 0.85 is adopted, the recording medium must have a uniform-thickness with a deviation less than ± 3 μm. However, it is very difficult to manufacture the recording medium within the above thickness deviation range.

$$W_{40}=\frac{n^2-1}{8n^3}(NA)^4\Delta d \qquad (2)$$

[0005] Figure 1 is a graph showing the relation between thickness deviation of the recording medium and wavefront aberration (optical path difference (OPD)) caused by the thickness deviation when a 400-nm light source and an objective lens having an NA of 0.85 are used. As shown in Figure 1, the wavefront aberration increases in proportion to the thickness deviation. Thus, when the objective lens having a high NA, for example, an NA of 0.85, is adopted, there is a need to correct for spherical aberration caused by the thickness deviation of the recording medium.

[0006] Figure 2 shows a conventional optical pickup capable of detecting variation of the thickness of an optical disc, which is disclosed in Japanese Patent Laid-open Publication No. hei 12-57616. Referring to Figure 2, the conventional optical pickup includes a light source 10 for emitting a light beam, a polarization beam splitter 11 for transmitting or reflecting an incident light beam according to its polarization, a quarter-wave plate 15 for changing the polarization of an incident light beam, an objective lens 17 for focusing an incident light beam to form a light spot on the recording surface 1a of an optical disc 1, a cylindrical astigmatism lens 21 having astigmatism affecting the light beam passed back through the objective lens 17, the quarter-wave plate 15, and the polarization beam splitter 11 after having been reflected from the recording surface 1a of the optical disc1, and a photodetector 25 for receiving the light beam from the astigmatism lens 21. The conventional optical pickup further includes a collimating lens disposed between the polarization beam splitter 11 and the quarter-wave plate 15, for collimating an incident diverging light beam from the light source, and a condensing lens 19 disposed between the polarization beam splitter 11 and the astigmatism lens 21.

[0007] Since the conventional optical pickup has the astigmatism lens 21 which causes astigmatism to enable focus error signal detection, the intensity distribution of light passed through the astigmatism lens 21 after having been reflected from the recording surface 1a of the optical disc 1 varies according to the thickness *t* of the optical disc, as shown in Figures 3A through 3E. Figures 3A through 3E illustrate the intensity distribution of light passed through the astigmatism lens 21 and heading toward the photodetector 25, when the optical disc 1 adopted has a thickness of 0.70 mm, 0.65 mm, 0.60 mm, 0.55 mm, and 0.50 mm, respectively, and the optical pickup of Figure 2 is designed for a 0.6-mm thick optical disc.

[0008] Referring to Figure 3C, when the optical disc 1 has a thickness of 0.60 mm, which is the level of reference with respect to the other thickness levels (hereinafter, referred to as the reference thickness), the intensity distribution of light entering the photodetector 25 is circular due to no occurrence of spherical aberration, and is symmetrical around the center point. When the thickness of the optical disc 1 deviates from 0.60 mm, spherical aberration occurs as a result of the thickness deviation, and the intensity distribution of light passed through the astigmatism lens 21 and received by the photodetector 25 is asymmetrical about the center point, as illustrated in Figures 3A, 3B, 3D and 3E.

[0009] The photodetector 25 detects the variation of thickness of the optical disc 1 from the variation of intensity distribution of the received light. To this end, the photodetector 25 includes first through fourth inner sections A_1, B_1, C_1 and D_1, and first through fourth outer sections A_2, B_2, C_2 and D_2 surrounding the first through fourth inner sections A_1, B_1, C_1 and D_1.

[0010] In a conventional optical pickup having the

configuration described above, a thickness variation signal for the optical disc 1 is detected by subtracting the sum ($a2+c2+b1+d1$) of the detection signals $a2$ and $c2$ of the first and third outer sections A_2 and C_2 in one diagonal direction of the photodetector 25, and the detection signals $b1$ and $d1$ of the second and fourth inner sections B_1 and D_1 in the other diagonal direction, from the sum ($a1+c1+b2+d2$) of the detection signals $a1$ and $c1$ of the first and third inner sections A_1 and C_1 in the one diagonal direction, and the detection signals $b2$ and $d2$ of the second and fourth outer sections B_2 and D_2 in the other diagonal direction. In other words, a thickness variation signal St' for an optical disc can be detected from the detection signals $a1$, $b1$, $c1$ and $d1$ of the first through fourth inner sections A_1, B_1, C_1 and D_1 of the photodetector 25, and the detection signals $a2$, $b2$, $c2$ and $d2$ of the first through fourth outer sections A_2, B_2, C_2 and D_2, by using the following equation:

$$St' = (a1 + c1 + b2 + d2) - (a2 + c2 + b1 + d1) \quad (3)$$

[0011] However, this mechanism of detecting variation of the thickness of an optical disc can be applied to only optical pickups adopting a lens with astigmatism. In other words, if an optical pickup does not include an astigmatism lens, thickness variation of an optical disc used with the optical pickup cannot be detected.

[0012] An aim of the present invention to provide an optical pickup capable of detecting variation of the thickness of a recording medium, and/or capable of compensating for spherical aberration caused by the thickness variation of a recording medium, without including an astigmatism lens for causing astigmatism at the light receiving side.

[0013] According to one aspect of the present invention, there is provided an optical pickup comprising: a light source for generating and emitting a light beam; an objective lens for focusing an incident light beam from the light source to form a light spot on a recording medium; an optical path changer disposed on the optical path between the light source and the objective lens, for altering the traveling path of an incident light beam; a light beam division and detection means for dividing a light beam passed through the objective lens and the optical path changer after having been reflected from the recording medium into a first light beam portion and a second light beam portion, and detects first and second detection signals from the first and second light beam portions; and a thickness variation detection circuit for detecting a variation of thickness of the recording medium by subtracting the second detection signal from the first detection signal.

[0014] Preferably, the light beam division and detection means may be a photodetector having first and second light receiving portions for dividing the incident light beam into the first and second light beam portions, receiving the first and second light beam portions, and separately and photoelectrically converting the first and second light beam portions.

[0015] Preferably, the light beam division and detection means comprises: a light beam divider for dividing the incident light beam into the first and second light beam portions; and first and second photodetectors for receiving the first and second light beam portions from the light beam divider, and photoelectrically converting the first and second light beam portions, respectively.

[0016] In another embodiment, the present invention provides an optical pickup comprising: a light source for generating and emitting a light beam; an objective lens for focusing an incident light beam from the light source to form a light spot on a recording medium; an optical path changer disposed on the optical path between the light source and the objective lens, for altering the traveling path of an incident light beam; a light beam division and detection means for dividing a light beam passed through the objective lens and the optical path changer after having been reflected from the recording medium into a first light beam portion on the optical axis and second and third light beam portions around the first light beam portion, and detecting first, second and third detection signals from the first, second and third light beam portions; and a thickness variation detection circuit for detecting a variation of thickness of the recording medium by subtracting the sum of the second and third detection signals from the first detection signal.

[0017] It is preferable that the light beam division and detection means is a photodetector having first, second and third light receiving portions for dividing the incident light beam into the first, second and third light beam portions, receiving the first, second and third light beam portions, and separately and photoelectrically converting the first, second and third light beam portions.

[0018] It is preferable that the light beam division and detection means comprises: a light beam divider for dividing the incident light beam into the first, second and third light beam portions; and first, second and third photodetectors for receiving the first, second and third light beam portions from the light beam divider, and photoelectrically converting the first, second and third light beam portions, respectively.

[0019] The optical pickups according to the present invention may further comprises a spherical aberration compensation element on the optical path between the optical path changer and the objective lens, for compensating for spherical aberration caused by thickness variation of the recording medium by being driven according to a thickness variation signal produced by the thickness variation detection circuit.

[0020] The optical pickups according to the present invention may further comprises: a collimating lens on the optical path between the light source and the objective lens, for collimating a diverging light beam from the light source; and an actuator for actuating the collimating lens according to a thickness variation signal detected by the thickness variation detection circuit, such that

spherical aberration caused by the thickness variation of the recording medium is compensated for.

[0021] For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which:

Figure 1 is a graph showing the relation between thickness deviation of a recording medium and wavefront aberration (optical path difference (OPD)) caused by the thickness deviation;

Figure 2 illustrates a conventional optical pickup capable of detecting thickness variation of an optical disc, which is disclosed in Japanese Patent Laid-open Publication No. hei 12-57616;

Figures 3A through 3E illustrate the distribution of light entering the photodetector of the optical pickup of Figure 2, which is designed for 0.60-mm thick optical discs, when the optical disc has a thickness of 0.70 mm, 0.65 mm, 0.60 mm, 0.55 mm, and 0.50 mm, respectively;

Figure 4 is a plan view illustrating the configuration of the photodetector shown in Figure 2;

Figure 5 shows a preferred embodiment of an optical pickup according to the present invention;

Figures 6A through 6C, and Figures 7A through 7C illustrate the intensity distribution and the phase distribution, respectively, of a light beam passed back through the objective lens and the optical path changer after having been reflected from the recording medium, with respect to variations of thickness of the recording medium, when the optical pickup of Figure 5 is designed for 0.1-mm thick recording media, the objective lens has a NA of 0.85, and the light source emits a 400-nm beam;

Figure 8 illustrates preferred embodiments of the photodetector of Figure 5 and a thickness variation detection circuit;

Figure 9 illustrates another embodiment of the thickness variation detection circuit of Figure 8;

Figure 10 illustrates other embodiments of the photodetector and the thickness variation detection circuit of Figure 5;

Figure 11 is a graph of the thickness variation signal and the sum of the first and second detection signals of the first and second light receiving portions of the photodetector when the photodetector of the optical pickup according to the present invention has the configuration of Figure 8;

Figure 12 is a graph of the thickness variation signal for the recording medium and the sum of the first, second and third detection signals of the first, second and third light receiving portions of the photodetector when the photodetector of the optical pickup according to the present invention has the configuration of Figure 10;

Figure 13 illustrates another preferred embodiment of the optical pickup according to the present invention;

Figure 14 illustrates another preferred embodiment of the optical pickup according to the present invention;

Figure 15 is a plan view showing the structure of the light beam divider of Figure 14;

Figure 16 illustrates another preferred embodiment of the optical pickup according to the present invention; and

Figure 17 is a plan view showing the structure of the light beam divider of Figure 16.

[0022] A preferred embodiment of an optical pickup according to the present invention is illustrated in Figure 5. Referring to Figure 5, the optical pickup includes a light source 51 for generating and emitting a light beam, an objective lens 57 for focusing an incident light beam from the light source 51 to form a light spot on an information recording surface 50a of a recording medium 50, an optical path changer disposed on the optical path between the light source 51 and the objective lens 57, for altering the traveling path of an incident light beam, a photodetector 65 for dividing and detecting the light beam passed back through the objective lens 57 and the optical path changer after having been reflected from the recording medium 50, and a thickness variation detection circuit 70 for detecting variation of the thickness of the recording medium 50 from a plurality of detection signals output from the photodetector 65. Here, the thickness t of the recording medium 50 means the distance from the light incident surface 50b of the recording medium 50 to the information recording surface 50a. Thickness variation refers to both thickness deviation according to position on one recording medium and a difference in thickness between different optical discs.

[0023] The light source 51 may be a semiconductor laser such as an edge emitting laser or a vertical cavity surface emitting laser (VCSEL). As the optical path changer, a beam splitter 55 for transmitting and reflecting an incident light beam in a predetermined ratio can be adopted. Alternatively, the optical path changer may include both a polarization beam splitter (not shown) for

selectively transmitting or reflecting an incident light beam according to its polarization, and a quarter-wave plate (not shown) disposed on the optical path between the polarization beam splitter and the objective lens 57, for changing the phase of an incident light beam.

[0024] To use the optical pickup according to the present invention for recording and reproduction with a next generation digital versatile disc (DVD), so-called "high-definition (HD)-DVD" family recording medium, it is preferable that a blue-light semiconductor laser which emits a light beam having a wavelength of about 400-420 nm, preferably, a wavelength of about 405 nm, is adopted as the light source 51, and a lens having a numerical aperture (NA) of 0.7 or more, preferably, an NA of 0.85, is adopted as the objective lens 57.

[0025] It is preferable that the optical pickup according to the present invention further includes a collimating lens 53 on the optical path between the light source 51 and the beam splitter 55, for collimating a diverging light beam emitted from the light source 51, and a sensing lens 59 on the optical path between the beam splitter 55 and the photodetector 65, for condensing an incident light beam. The distance between the sensing lens 59 and the photodetector 65 is determined such that the light spot received by the photodetector 65 has an appropriate size, for example, has a diameter of about 100 μm.

[0026] The photodetector 65 as a light beam division and detection means is constructed such that it is able to divide and detect the light beam passed back through the objective lens 57 and the optical path changer after having been reflected from the recording medium, taking into account variation in the intensity distribution of the light beam according to thickness variation of the recording medium 50.

[0027] For example, it is assumed that the objective lens 57 has a NA of 0.85, the optical pickup is designed for the recording medium 50 having a thickness of 0.1 mm, and the light source 51 emits a 400-nm light beam. For this case, the intensity distribution and phase distribution of light beam LB passed back through the objective lens 57 and the optical path changer after having been reflected from the recording medium 50 with respect to the variation of thickness of the recording medium 50 are shown in Figures 6A through 6C, and Figures 7A through 7C. In particular, Figure 6A illustrates the intensity distribution of light passed through the optical path changer after having been reflected from the recording medium 50 which is 10 μm thinner than 0.1 mm thickness for which the optical pickup is designed (hereinafter referred to as the reference thickness), and Figure 7A illustrates the phase distribution of the light beam of Figure 6A. Figure 6B illustrates the distribution of light for the recording medium 50 having the reference thickness of 0.1 mm, and Figure 7B shows the phase distribution of the light beam of Figure 6B. Figure 6C illustrates the distribution of light for the recording medium 50 which is 10 μm thicker than the reference thickness, and Figure 7C illustrates the phase distribution of the light beam of Figure 6C.

[0028] Referring to Figures 6A and 7A, when a portion of the recording medium 50 which the light beam is focused on is thinner than the reference thickness, the intensity distribution of the light beam is weaker at the central axis, and increases with increased distance from the central axis. Also, the phase distribution of the light beam appears like twin peaks symmetrical with respect to the central axis. Referring to Figures 6B and 7B, when a portion of the recording medium 50 which the light beam is focused on has the reference thickness, the intensity distribution of light is uniform across the light beam, and phase distribution is uniform. Referring to Figures 6C and 7C, when a portion of the recording medium 50 which the light beam is focused on is thicker than the reference thickness, the intensity distribution and phase distribution of the light beam are inversed with respect to those of Figures 6A and 7A.

[0029] As illustrated in Figures 6A through 6C, and Figures 7A through 7C, the intensity distribution and phase distribution of the light beam according to the thickness variations of the recording medium 50 vary symmetrically around the central axis and are opposite with respect to inversed thickness variations. Furthermore, variations in the distribution and phase spectrum of the light beam caused by an increase in the thickness of the recording medium above the reference thickness are opposite to those by a decrease in the thickness of the recording medium below the reference thickness.

[0030] For this reason, it is preferable that the photodetector 65 is constructed such that it separately detects the incident light beam into a portion of LB on the optical axis and a portion in the periphery. For example, as shown in Figure 8, the photodetector 65 may include first and second light receiving portions A and B for dividing the incident light beam LB into a first light beam portion corresponding to the central optical axis, and a second light beam portion around the first light beam portion, and for photoelectrically converting the first and second light beam portions. In this case, the first light receiving portion A of the photodetector 65 may have a circular or rectangular form which allows division of the incident light beam LB into the first light beam portion corresponding to the central optical axis, and the second light beam portion around the first light beam portion, and separate detection of the two portions.

[0031] When the photodetector 65 includes the first and second light receiving portions A and B, as shown in Figure 8, the thickness variation detection circuit 70 is constructed with a subtractor 71 for subtracting a second detection signal *b* of the second light receiving portion B from a first detection signal *a* of the first light receiving portion A and outputting the result of the subtraction as a thickness variation signal St for the recording medium 50. In this case, as shown in Figure 9, the thickness variation detection circuit 70 may further comprise a gain controller 73 for amplifying at least one of

the first and second detection signals a and b with a predetermined gain factor k prior to the subtraction by the subtractor 71, such that offset of the thickness variation signal St can be adjusted.

[0032] Alternatively, as shown in Figure 10, the photodetector 65 may include first, second and third light receiving portions D, E and F for separately dividing the incident light beam LB into a first light beam portion aligned on the optical axis, and second and third light beam portions around the first light beam portion of the incident light beam LB, and for separately and photoelectrically converting the light beam portions. The first, second and third light receiving portions D, E and F may be arranged in a direction corresponding to either the tangential or radial direction of the recording medium 50.

[0033] When the photodetector 65 is constructed as illustrated in Figure 10, the thickness variation detection circuit 70 detects the variation of thickness of the recording medium 50 by subtracting the sum of the second and third detection signals e and f of the second and third light receiving portions E and F from the first detection signal d of the first light receiving portion D. As illustrated in Figure 9, the thickness variation detection circuit 70 may be constructed such that it is able to amplify at least one of the first, second and third detection signals d, e and f with a predetermined gain factor k, and then to process the detection signals, so that offset of the thickness variation signal can be adjusted.

[0034] For the photodetector 65 illustrated in Figures 8 and 10, the size of the first light receiving portions A and D is determined such that they receive 10-90% of the entire incident light beam.

[0035] Turning back to Figure 5, the optical pickup according to the present invention may further include a spherical aberration compensation element 75 on the optical path between the optical path changer and the objective lens 57, which is driven according to the thickness variation signal St produced by the thickness variation detection circuit 70, thereby compensating for spherical aberration caused by thickness variation of the recording medium 50.

[0036] As the spherical aberration compensation element 75, a liquid crystal plate manufactured by injecting liquid crystals between two sheets of transparent substrates having electrode patterns can be used. Due to the anisotropic property of liquid crystal with respect to refractive index, the phase of the light beam passing through the liquid crystal plate changes. In particular, the liquid crystal plate is driven according to the thickness variation signal St such that the shape of the wavefront of the light beam passing the liquid crystal plate is changed into the inverse shape of spherical aberration caused by the thickness variation of the recording medium 50, thereby compensating for the spherical aberration caused by the thickness variation of the recording medium 50. In this case, a driving circuit for driving the spherical aberration compensation element 75 may be included in or separately from the thickness variation detection circuit 70.

[0037] Figure 11 is a graph of the thickness variation signal St and the sum Ssum of the first and second detection signals a and b of the first and second light receiving portions A and B of the photodetector 65 versus the thickness variation of the recording medium 50 when the photodetector 65 of the optical pickup of the present invention has the configuration of Figure 8. Figure 12 is a graph of the thickness variation signal St and the sum Ssum of the first, second and third detection signals d, e and f of the first, second and third light receiving portions D, E and F of the photodetector 65 versus the thickness variation of the recording medium 50, when the photodetector 65 of the optical pickup of the present invention has the configuration of Figure 10. As shown in Figures 11 and 12, the variation of the thickness variation signal St detected by the thickness variation detection circuit 70 with respect to the thickness variation of the recording medium 50 is relatively larger than the variation of the sum Ssum of the detection signals detected by the photodetector 65.

[0038] As described with reference to Figures 11 and 12, the variation of thickness of the recording medium 50 can be detected by the optical pickup of the present invention. Thus, the spherical aberration caused by the thickness variation of the recording medium 50 can be corrected by driving the spherical aberration compensation element 75 according to the thickness variation signal St.

[0039] Meanwhile, for the purpose of compensating for spherical aberration caused by thickness variation of the recording medium 50, the optical pickup according to the present invention may include an actuator 80 capable of actuating the collimating lens 53 along the optical axis according to the thickness variation signal St produced by the thickness variation detection circuit 70, as shown in Figure 13, instead of the spherical aberration correction element 75 of Figure 5.

[0040] Figure 14 illustrates another embodiment of the optical pickup according to the present invention. In the present embodiment, instead of the photodetector 65 having the divided configuration shown in Figure 8, a light beam divider 160, and first and second photodetectors 165a and 165b are used as a light beam division and detection means. In Figure 14, the same elements as in Figure 5 are denoted by the same reference numerals, and descriptions thereof will not be provided here.

[0041] The light beam divider 160 includes first and second sections A' and B' as shown in Figure 15 for dividing the incident light beam LB into a first light beam portion on the optical axis, and a second light beam portion around the first light beam portion. The first section A' directly transmits, for example, the first light beam portion of the incident light beam LB, or diffracts the same into 0^{th}-order beam, so that the transmitted or diffracted light beam is received by the first photodetector 165a. The second section B' diffracts, for example, the

second light beam portion of the incident light beam LB so that a +1st-order or -1st order beam is received by the second photodetector 165b. As the light beam divider 160, a hologram optical element (HOE), which has in the first section A' a through hole, direct transmit portion, or hologram pattern for diffracting an incident light beam and transmitting a resulting 0th-order beam, and has in the second section B' a hologram pattern for diffracting an incident light beam and transmitting a resulting +1st-order or -1st-order beam.

[0042] In the optical pickup according to the embodiment of the present invention shown in Figure 14, the principle of detecting the thickness variation signal St for the recording medium 50 from the first and second detection signals *a* and *b* of the first and second photodetectors 165a and 165b, and correcting the spherical aberration caused by the thickness variation of the recording medium 50 by driving the spherical aberration compensation element 75 according to the thickness variation signal St, is the same as in the previous embodiments. Alternatively, the optical pickup of Figure 14 may include the actuator 80 for actuating the collimating lens 53 along the optical axis, as shown in Figure 13, thereby compensating for spherical aberration caused by thickness variation of the recording medium 50.

[0043] Figure 16 illustrates another preferred embodiment of the optical pickup according to the present invention. In the present embodiment, instead of the photodetector 65 having the divided configuration shown in Figure 10, a light beam divider 260, and first, second and third photodetectors 265d, 265e and 265f are used as a light beam division and detection means. In Figure 16, the same elements as in Figure 5 are denoted by the same reference numerals, and descriptions thereof will not be provided here.

[0044] In the embodiment shown in Figure 16, the light beam divider 260 includes first, second and third sections D', E' and F', as shown in Figure 17, for dividing the incident light beam LB into a first light beam portion on the optical axis, and second and third light beam portions around the first light beam portion, based on a principle similar to the light beam divider 160 of Figure 15. The first section D' directly transmits, for example, the first light beam portion of the incident light beam LB, or diffracts the same and transmits the resulting 0th-order beam, so that the transmitted or diffracted light beam is received by the first photodetector 265d. The second section E' diffracts, for example, the second light beam portion of the incident light beam LB so that the +1st-order or -1st order diffracted light beam is received by the second photodetector 265e. The third section F' diffracts, for example, the third light beam portion of the incident light beam LB so that the -1st-order or +1st order diffracted light beam is received by the third photodetector 265f. As the light beam divider 160, an HOE, which has in the first section D' a through hole, direct transmit portion, or hologram pattern for diffracting an incident light beam, and has in both the second and third sections E' and F' a hologram pattern for diffracting an incident light beam, can be used.

[0045] In the optical pickup according to the embodiment of the present invention shown in Figure 16, the principle of detecting the thickness variation signal St for the recording medium 50 from the first, second and third detection signals *d, e* and *f* of the first, second and third photodetectors 265d, 265e and 265f, and compensating for the spherical aberration caused by thickness variation of the recording medium 50 by driving the spherical aberration compensation element 75 or the collimating lens 53 according to the detected thickness variation signal St is the same as in the previous embodiments.

[0046] As described above, in the optical pickups according to the present invention, a single photodetector having a divided configuration, or a light beam divider and a plurality of photodetectors is used as a light beam division and detection means, so that the light beam passed through the objective lens and the optical path changer after having been reflected from the recording medium is divided and detected by the light beam division and detection means, taking into account variation in the intensity distribution of light caused by thickness variation of the recording medium. The thickness variation signal is detected by processing the detection signals output from the photodetector. Thus, variation of thickness of the recording medium can be detected with an optical system including no astigmatism lens installed to cause astigmatism at the light receiving side of the optical pickup. Spherical aberration caused by thickness variation of the recording medium can be corrected by driving the spherical aberration compensation element or the collimating lens along the optical axis according to the detected thickness variation signal.

[0047] While this invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made thereto without departing from the scope of the invention as defined by the appended claims.

[0048] The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0049] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0050] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated

otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0051] The invention is not restricted to the details of the foregoing embodiment(s). The invention extend to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. An optical pickup including a light source (51) for generating and emitting a light beam, an objective lens (57) for focusing an incident light beam from the light source to form a light spot on a recording medium (50), and an optical path changer (55) disposed on the optical path between the light source (51) and the objective lens (57), for altering the traveling path of an incident light beam, the optical pickup being **characterized by** comprising;

   a light beam division and detection means (65) for dividing a light beam passed through the objective lens (57) and the optical path changer (55) after having been reflected from the recording medium into a first light beam portion and a second light beam portion, and detects first and second detection signals from the first and second light beam portions; and

   a thickness variation detection circuit (70) for detecting a variation of thickness of the recording medium by subtracting the second detection signal from the first detection signal.

2. The optical pickup of claim 1, wherein the light beam division and detection means (65) is a photodetector having first and second light receiving portions (A,B) for dividing the incident light beam into the first and second light beam portions, receiving the first and second light beam portions, and separately and photoelectrically converting the first and second light beam portions.

3. The optical pickup of claim 1, wherein the light beam division and detection means comprises:

   a light beam divider (160) for dividing the incident light beam into the first and second light beam portions; and

   first and second photodetectors (165a,b) for receiving the first and second light beam portions from the light beam divider, and photoelectrically converting the first and second light beam portions, respectively.

4. The optical pickup of any of claims 1 through 3, wherein the light beam division and detection means (65) is constructed such that the light beam is divided into and detected as a circular or rectangular first light beam portion and second light beam portions surrounding the first light beam portion.

5. The optical pickup of claim 4, wherein the first light beam portion corresponds to 10-90% of the entire incident light beam.

6. The optical pickup of any of claims 1 through 3, wherein the thickness variation detection circuit (70) amplifies (73) at least one of the first and second detection signals with a predetermined gain factor, and then processes (71) the first and second detection signals to detect the thickness variation of the recording medium.

7. An optical pickup including a light source (51) for generating and emitting a light beam, an objective lens (57) for focusing an incident light beam from the light source to form a light spot on a recording medium, and an optical path changer (55) disposed on the optical path between the light source and the objective lens, for altering the traveling path of an incident light beam; the optical pickup being **characterized by** comprising:

   a light beam division and detection means (65) for dividing a light beam passed through the objective lens and the optical path changer after having been reflected from the recording medium into a first light beam portion on the optical axis and second and third light beam portions around the first light beam portion, and detecting first, second and third detection signals from the first, second and third light beam portions; and

   a thickness variation detection circuit (70) for detecting a variation of thickness of the recording medium by subtracting the sum of the second and third detection signals from the first detection signal.

8. The optical pickup of claim 7, wherein the light beam division and detection means (65) is a photodetector having first, second and third light receiving portions for dividing the incident light beam into the first, second and third light beam portions, receiving the first, second and third light beam portions, and separately and photoelectrically converting the first, second and third light beam portions.

9. The optical pickup of claim 1, wherein the light beam division and detection means (65) comprises:

   a light beam divider (260) for dividing the inci-

dent light beam into the first, second and third light beam portions; and

first, second and third photodetectors (265 d.e.f) for receiving the first, second and third light beam portions from the light beam divider. and photoelectrically converting the first, second and third light beam portions, respectively.

10. The optical pickup of any of claims 7 through 9, wherein the thickness variation detection circuit (70) amplifies at least one of the first, second and third detection signals with a predetermined gain factor. and then processes (71) the first, second and third detection signals to detect the thickness variation of the recording medium.

11. The optical pickup of any of claims 1 through 3, and claims 7 through 9, wherein the first light beam portion corresponds to 10-90% of the entire incident light beam

12. The optical pickup of any of claims 1 through 3, and claims 7 through 9, further comprising a spherical aberration compensation element (75) on the optical path betwoen the optical path changer and the objective lens. for compensating for spherical aberration caused by thickness variation of the recording medium by being driven according to a thickness variation signal produced by the thickness variation detection circuit (70).

13. The optical pickup of any of claims 1 through 3, and claims 7 through 9, further comprising:

a collimating lens (53) on the optical path between the light source (51) and the objective lens (57). for collimating a diverging light beam from the light source; and

an actuator (80) for actuating the collimating lens according to a thickness variation signal detected by the thickness variation detection circuit. such that spherical aberration caused by the thickness variation of the recording medium is compensated for.

FIG. 1 (PRIOR ART)

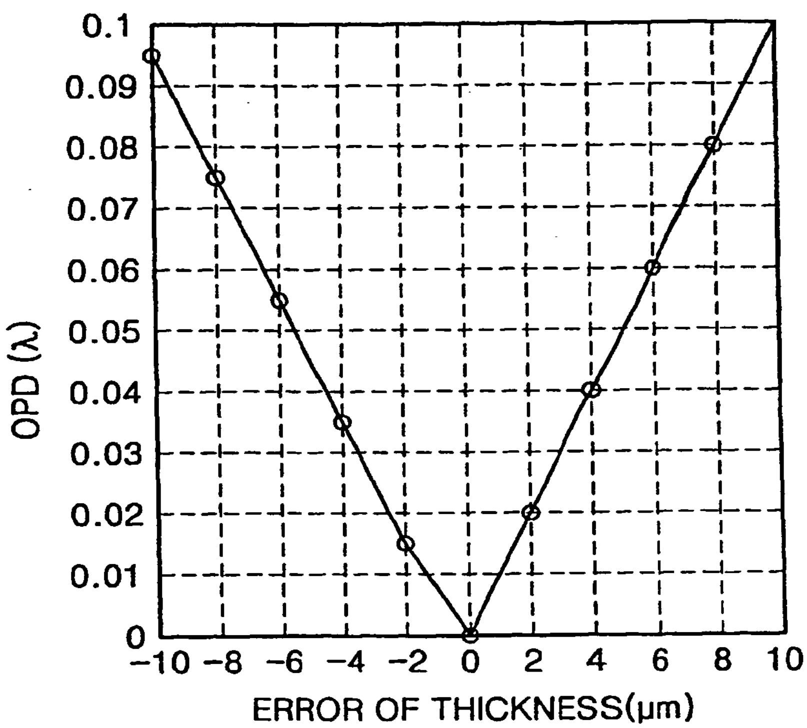

FIG. 2 (PRIOR ART)

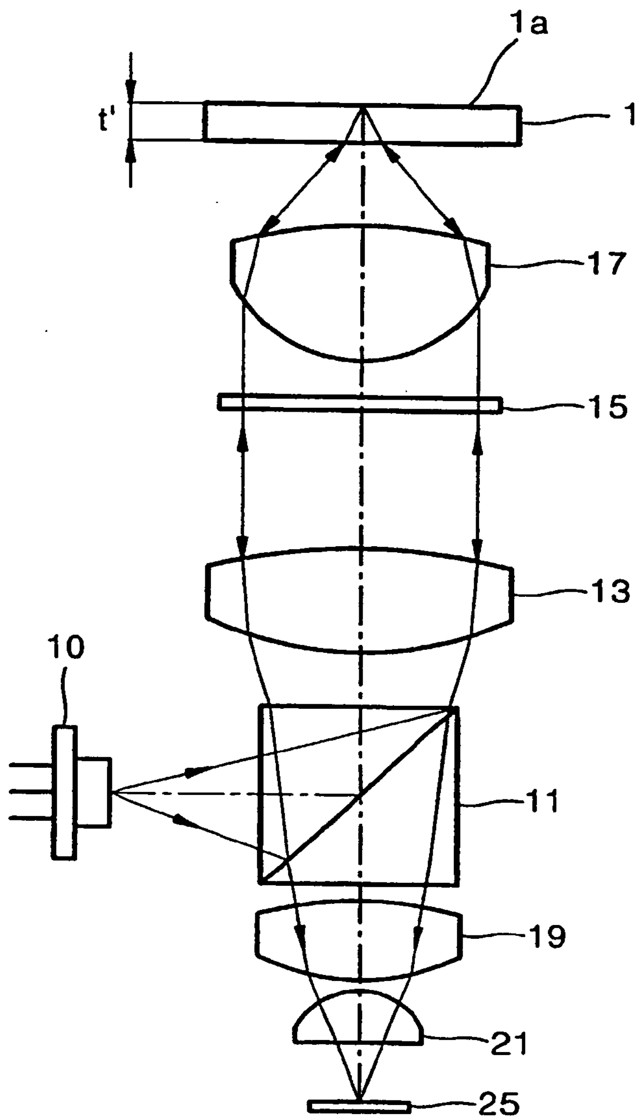

FIG. 3A (PRIOR ART)

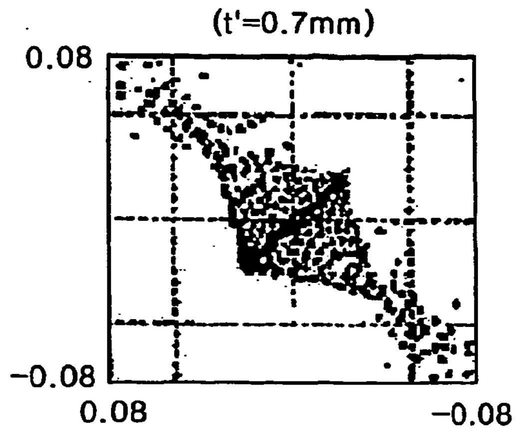

FIG. 3B (PRIOR ART)

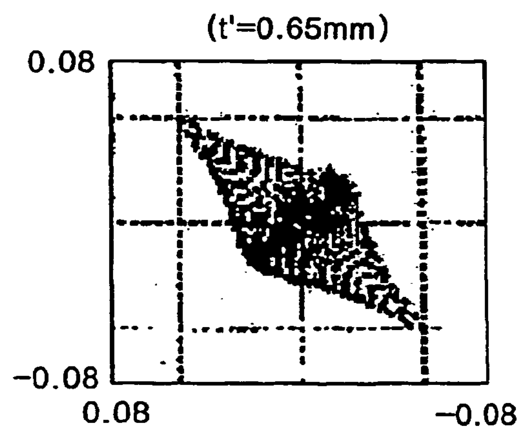

FIG. 3C (PRIOR ART)

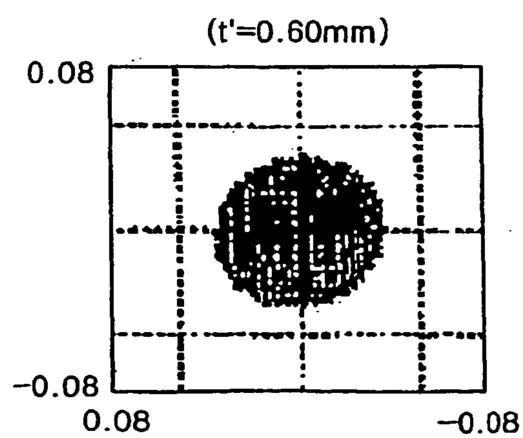

FIG. 3D (PRIOR ART)

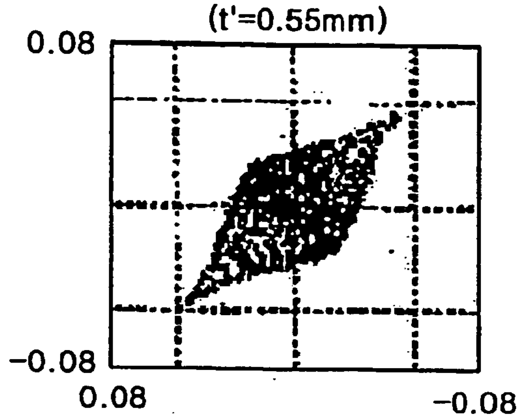

FIG. 3E (PRIOR ART)

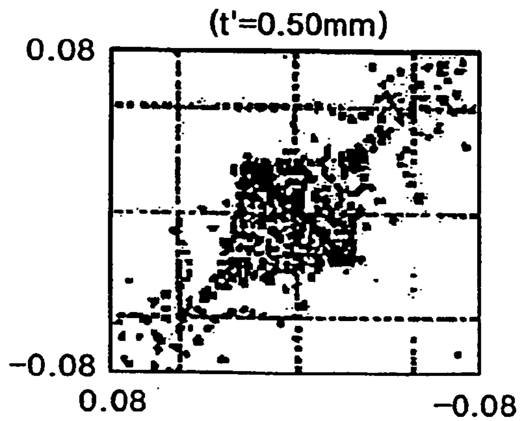

FIG. 4 (PRIOR ART)

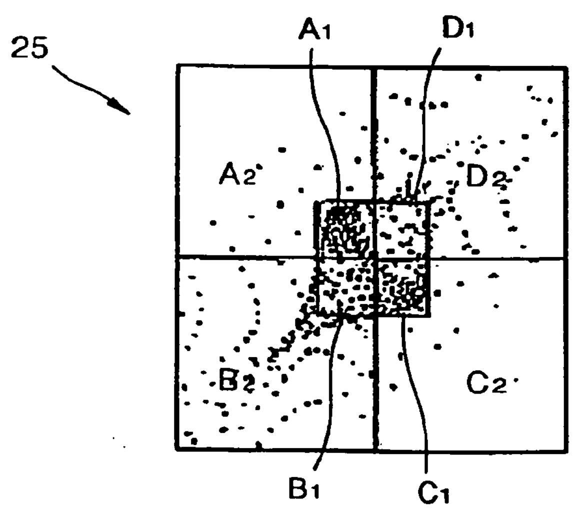

FIG. 5

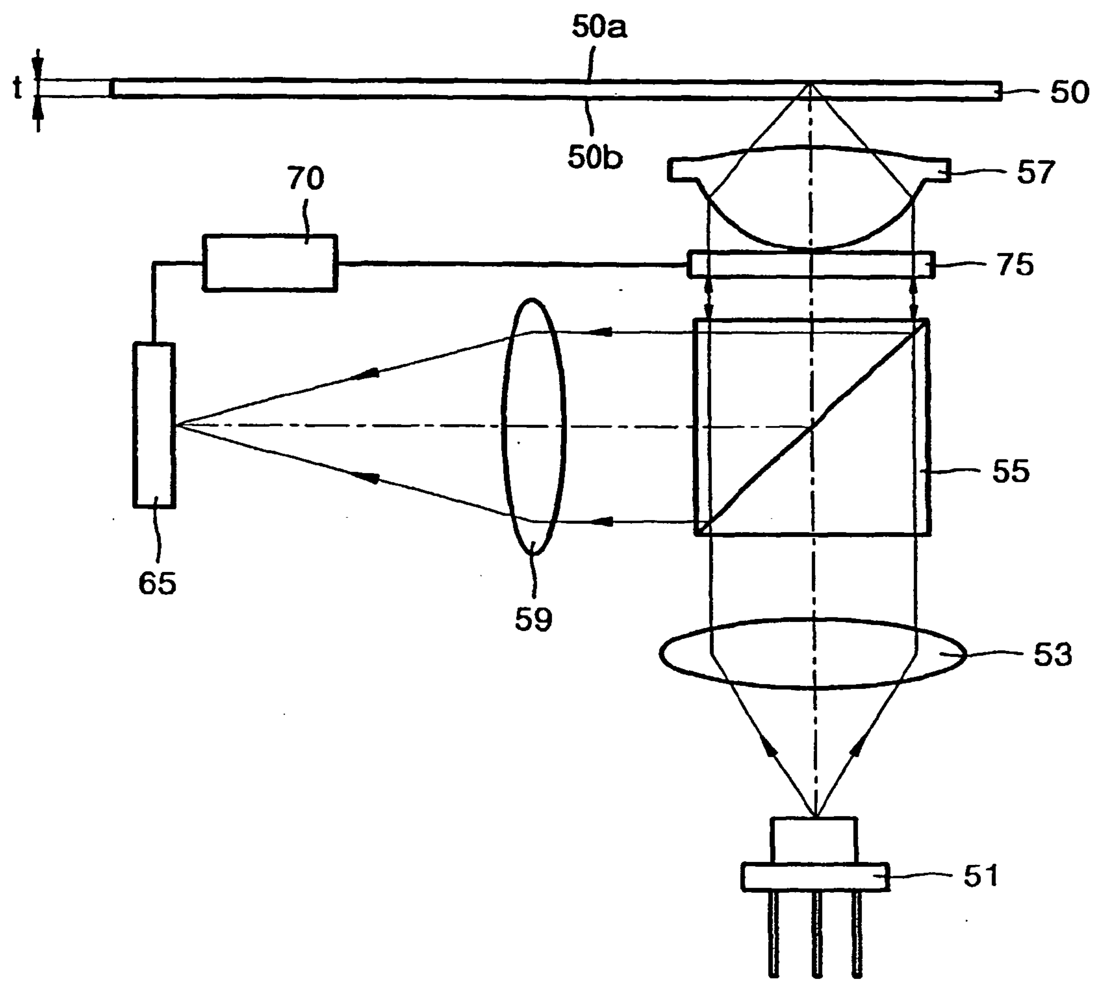

FIG. 6A

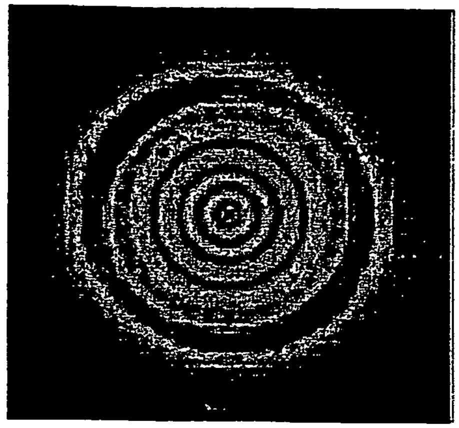

FIG. 6B

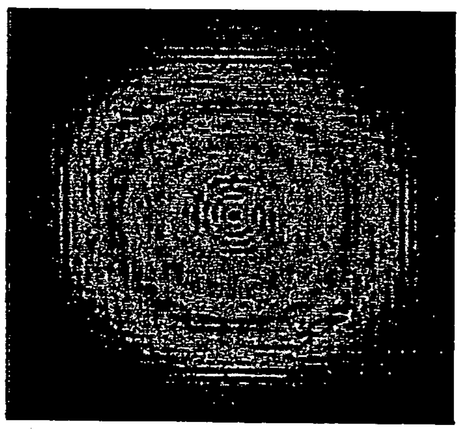

FIG. 6C

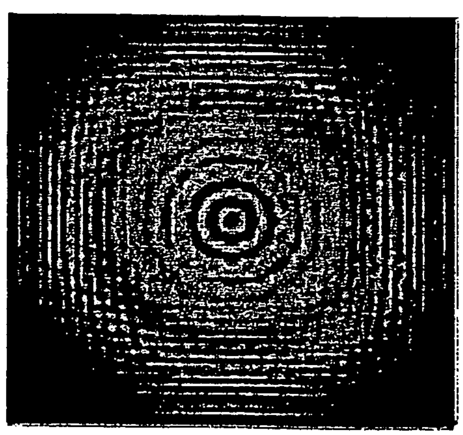

FIG. 7A

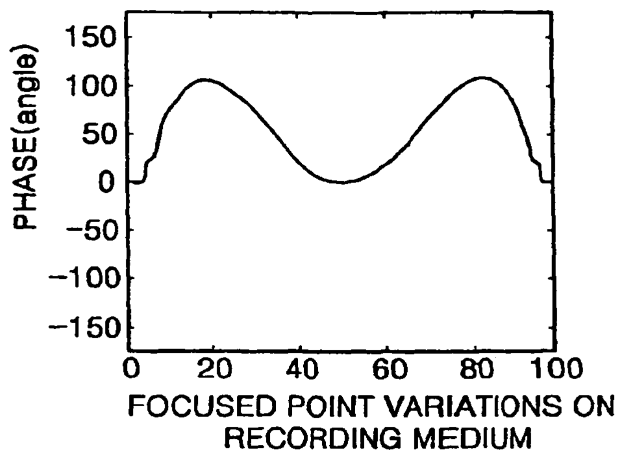

FIG. 7B

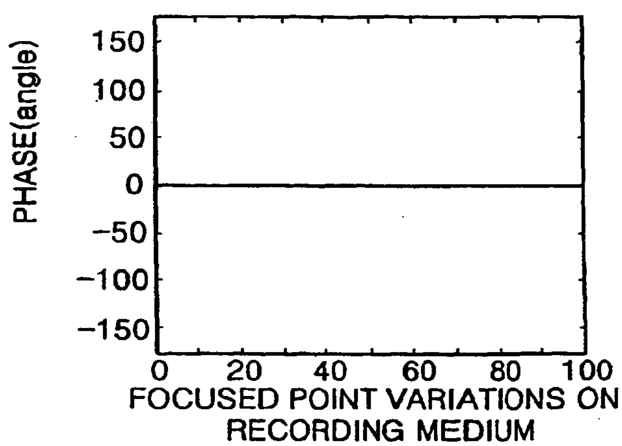

FIG. 7C

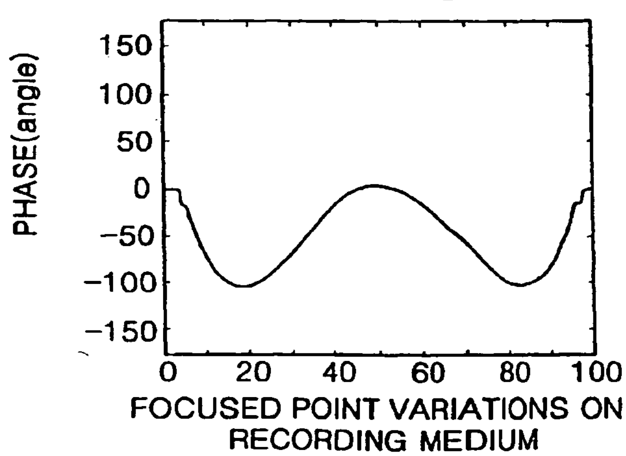

FIG. 8

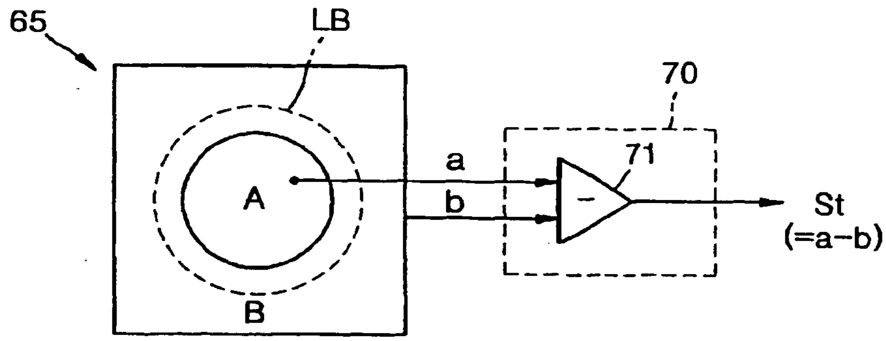

FIG. 9

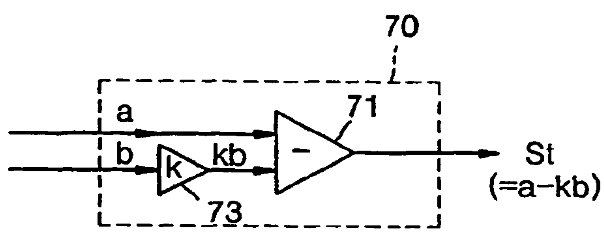

FIG. 10

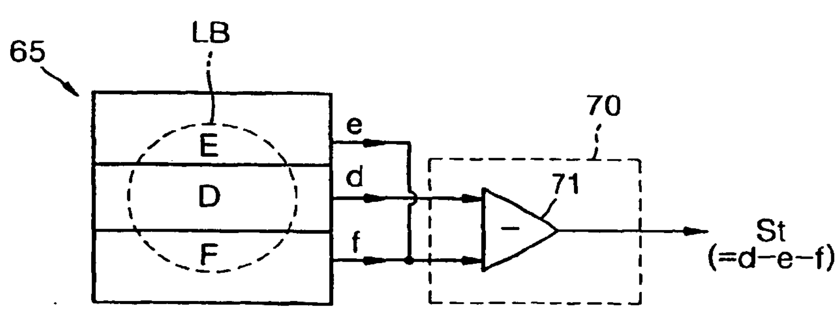

FIG. 11

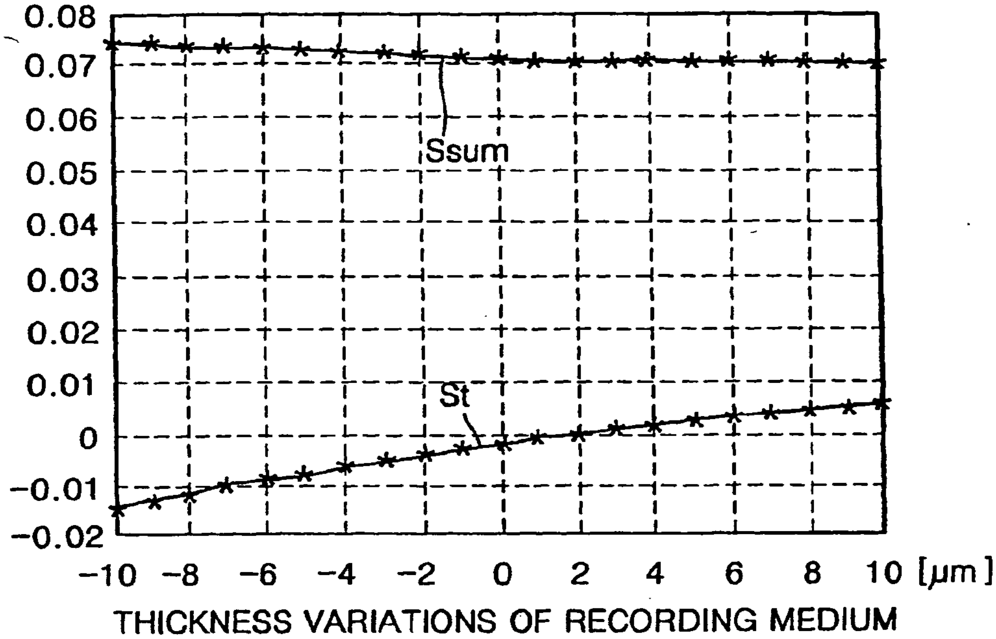
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
Ssum
St
−10 −8 −6 −4 −2 0 2 4 6 8 10 [μm]
THICKNESS VARIATIONS OF RECORDING MEDIUM

FIG. 12

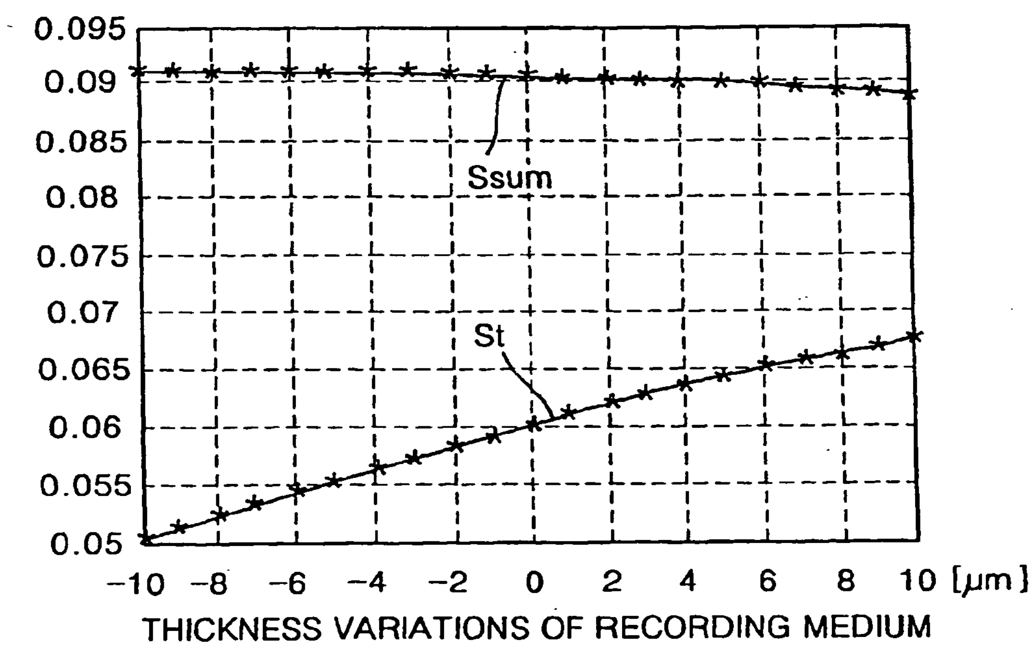
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
Ssum
St
−10 −8 −6 −4 −2 0 2 4 6 8 10 [μm]
THICKNESS VARIATIONS OF RECORDING MEDIUM

FIG. 13

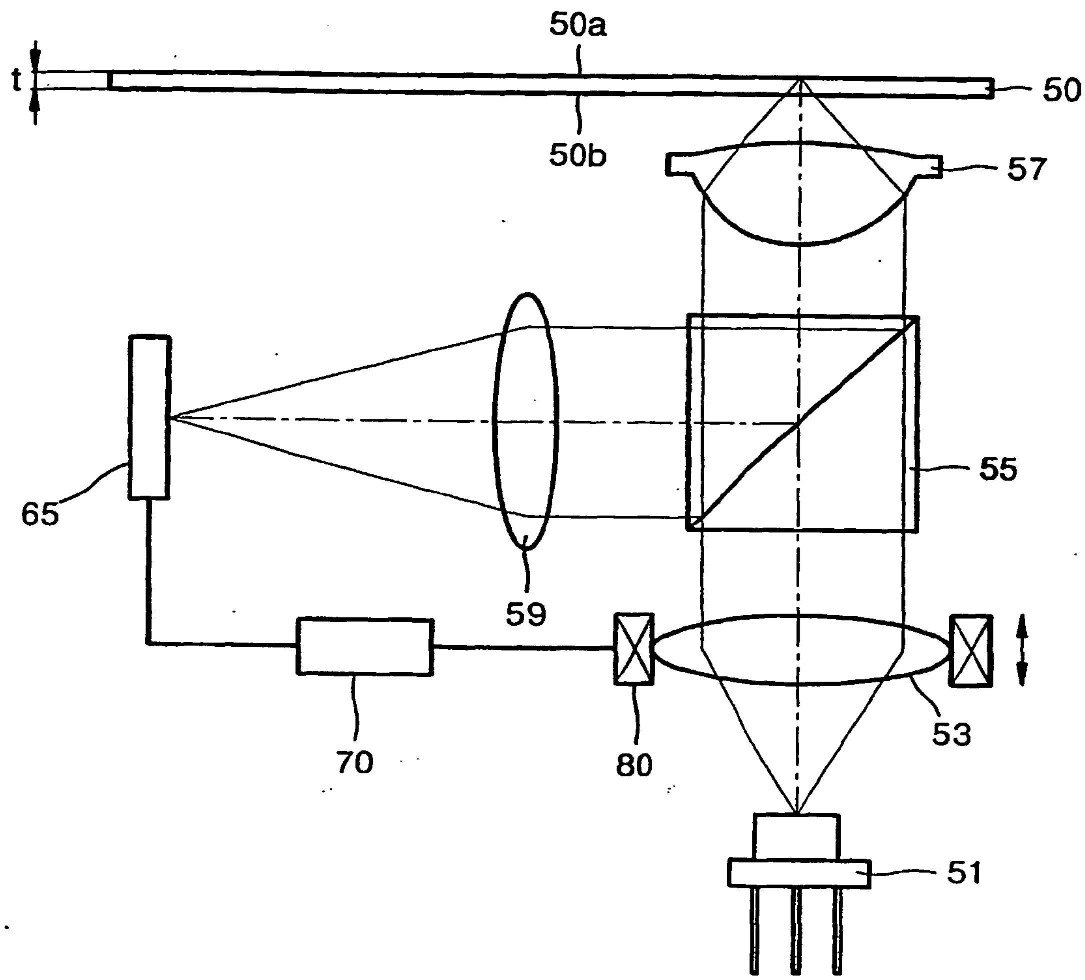

FIG. 14

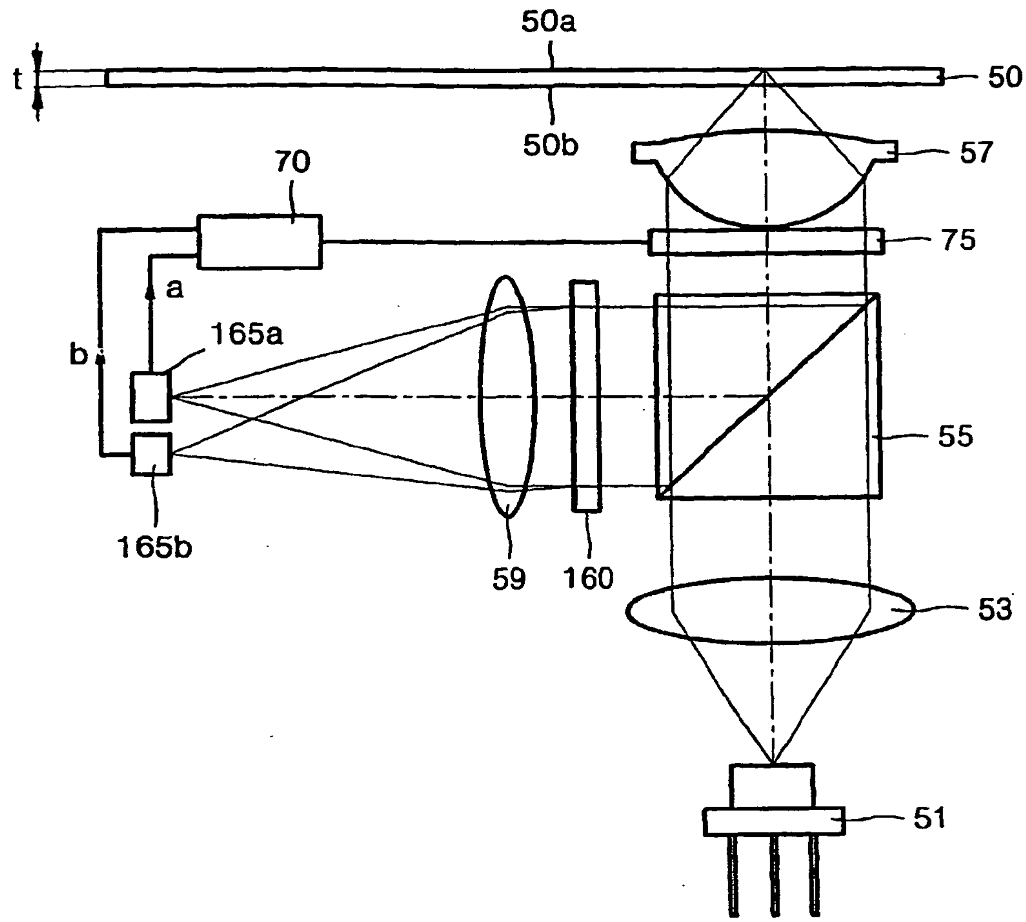

FIG. 15

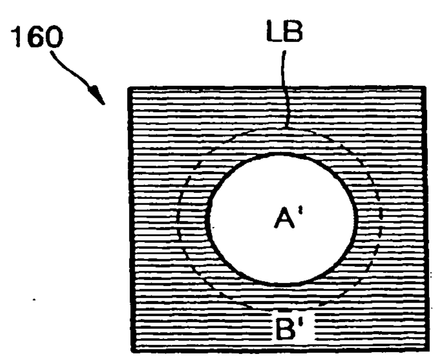

FIG. 16

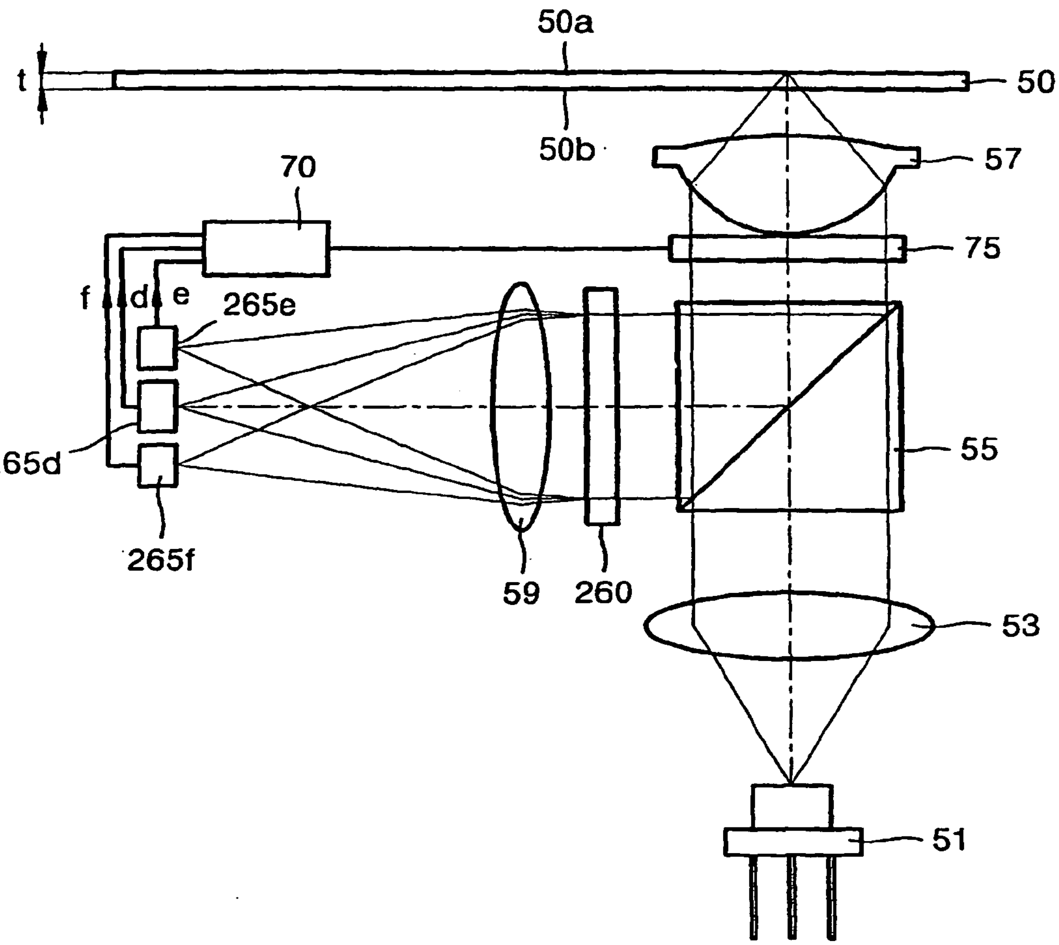

FIG. 17